AUTOMATIC CONTROL VALVE USING SERVO MOTOR

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ABSTRACT

This thesis is about developing a small scale control system to control the flow rate of water by using a servo control valve. Arduino board as the microcontroller was used to make a control plant much easier. The simplify C/C++ programming language also is use to make control system coding. A servo motor with known characteristic in controlling the position with high accuracy and timing has been chosen to implement as a control valve in order to reduce error. This project originally is the flume project.A control valve controls the flow and velocity of water to maintain laminar flow before entering the flume. By accurate valve opening using servo motor and interface of Arduino programming language It is possible to develop a better control system in a large scale project on the future. The theory have been proved as the larger valve opening results in larger flow rate value. Based on the result, these small scale control flow system are capable to gradually reduce cost especially in control valve. The result also shows that using Arduino microcontroller a friendly-users control system efficiently.

ABSTRAK

Tesis ini membentangkan berkenaan pembikinan sistem kawalan skala kecil yang bertujuan mengawal aliran air dengan menggunakan injap yang dikawal oleh motor servo. Dengan menggunakan papan Arduino sebagai *microcontroller,* secara tidak langsung, langkah-langkah membina system kawalan menjadi lebih mudah. Program bahasa C/C++ yang dipermudah juga sangat efisien digunakan menjadikan pembikinan kod bahasa lancar dan berkesan. Motor servo yang dikenali dengan ketepatan mengawal masa pergerakan dan posisinya juga telah menjadi pilihan saya untuk diimplementasikan dalam injap bola sebagai injap kawalan bertujuan mengurangkan seminimum mungkin ralat yang mungkin terjadi sepanjang eksperimen. Idea asal pembikinan projek ini adalah untuk diimplementasikan ke dalam bahagian kawalan injap dalam projek terowong air untuk mengawal aliran dan kelajuan air agar sentiasa dalam keadaan laminar sebelum masuk ke dalam terowong air. Dengan kombinasi ketepatan kawalan pembukaan injap menggunakan motor servo dan keberkesanan penggunaan program bahasa Arduino, adalah tidak mustahil untuk membina sebuah sistem kawalan skala besar pada masa hadapan. Melalui projek ini, masih terdapat beberapa faktor yang perlu diberi perhatian kerana mampu memberi kesan kepada hasil yang diperlukan seperti *head loss,* kejatuhan takanan, dan sistem paip. Keputusan daripada kedua-dua eksperimen menunjukkan perbezaan nilai menunjukkan kepada kita, faktor-faktor sedemikian tidak boleh diabaikan. Namun demikian, keputusan menunjukkan teori kepada semakin besar pembukaan injap semakin besar nilai aliran telah Berjaya dibuktikan. Berdasarkan hasil projek ini juga memperlihatkan kepada kita sistem kawalan air skala kecil ini mampu mengurangkan kos dengan drastik melalui injap motor buatan sendiri, malah menunjukkan tanda yang baik dengan menggunakan *microcontroller* Arduino ini mampu menghasilkan sistem kawalan mesra pengguna dengan berkesan dan mudah digunakan.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Flume is one kind of water tunnel or we can say as the model of the real river that use to measure the fluid flowrate and the hydrodynamics behaviour of submerged bodies in flowing water. The type of flume use also depends on the specific factors including for the precision and cost. In measuring water in open drain or river, its reliable to use flume in order to avoid the need for dewatering prior to the installation. The design of the flume must consider as the flow inside the flume and before it enters the flume has to be laminar and not turbulent. This is to make sure we can measured the flow rate of the water besides other dynamic data of the fluid that went through the flume. The flume also can be used to measure the flow of wave or small streams. Zulfadhli (2008) has stated that every type of flume have it own standard equation to calculate discharge value.

The control valve is one of the important component that usually been put at the inlet and outlet of the flume. The control valve is something that we can adjust to get the velocity that we desired. In this case the valve area that we must change to get the appropriate velocity. So, the accurate velocity of the flume must be adjust using the valve to make sure the flow in the flume will be laminar.

Control system is a system, device or set of device that manages,commands, directs or regulates the behaviour of other devices that we can control its behaviour or characteristics by using other devices or systems. Mastascusa (1999) said that when

controlling a system, the first thing to know is what the systems itself want to control and how well it is doing.

1.2 Objective

There are two objectives in this project. There are:

i. To developed automatic control valve by using a servo motor at the inlet of the flume that can be adjusted its opening area in order to get the appropriate flow rate.
ii. To test and evaluate the automatic control valve performance.

1.3 Scope

The scopes in this project are investigation of relationship between valve opening area and water flow rate in 2 metre flume to get the accurate range of flow. Besides that, this project also will focus on the developing of Arduino programming language coding to control the RC servo motor that implemented at ½ ball valve handle with 0º until 90º opening.

1.4 Problem Statement

The flume project is widely known as its capability to measure the hydrodynamics behaviours of fluid. However there are several factors that need to be considered before running experiment. The challenge in this project is how to maintain and confirm that the flow inside it is always laminar. Prior to this only manual operated valve was used in flume project, such that it is difficult to adjust the desired speed. Therefore an automatic control valve with high accuracy opening valve area is needed to get appropriate speed that is fulfilled the condition to maintain the fluid flow to be laminar before its entering the flume.

1.5 Overview of Report

Chapter 1 mainly briefs about the background of the project which involves the background of the projects, objectives, scopes and problem statements. Chapter 2 basically describes more about the studies ofthe components involved in this projects such as Arduino board, RC servo motor, ball valve and water flow sensor. Chapter 3 introduces the experimental procedures that shows step by step process from the circuit connection, developing of programming language coding and experimental setup. Chapter 4 mainly discuss about the results obtained during the experiment. Chapter 5 discuss about the conclusions that can be derived from this report and suggestion for future recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 THE THEORY OF CONTROL SYSTEM

Why control system is important in life? When we having a device, such as a car, how it be if the speed cannot be controlled? Another example is a vehicle when the driver himself can't ever control its direction where to go.From this question its clearly show how important a mechanism should be use on these devices to control it and that is a control system(Mastascusa,1999). Thus in the control system world, we have input which is the desired output that we want. In the chapter 2.2.1 we will discuss about how we use the information we get from the output to correct the error of the control system.

Figure 2.1: Basic control system diagram

Sources**:**E.JMastascusa, 1999

2.1.1 Feedback Control System (Closed-Loop)

By using the closed-loop system, those errors made by the disturbances can be overcome (Nise, 2011). This also is an advantage of close-loop system compare to open-loop system which can't correct the errors made by the disturbance and directly only take command from the input we enter. The best example of the open-loop system is on the washing machine application. Maybe we can set how long the operation and what type of fabrics we want to clean, but the output which is the cleanliness of the clothes, we can't measure it. The term of 'closed-loop' also is referred as the feedback control action in order to decrease the error of the system (Ogata, 2010). The figure 2.2 below shows how the sensor react as the feedback action as its measure the output value. Ogata also said but there certain case whereas there is no disturbance and using time as its base, it's more reliable to use open-loop system. We can see this application on traffic light system as example. In traffic lights system, actually the computer will control the sequences of lights displayed at a cross-roads to ensure that cars do not crash. Additionally the computer operates a pedestrian crossing to let pedestrians cross the road when a button is pressed(Meakin,1998).

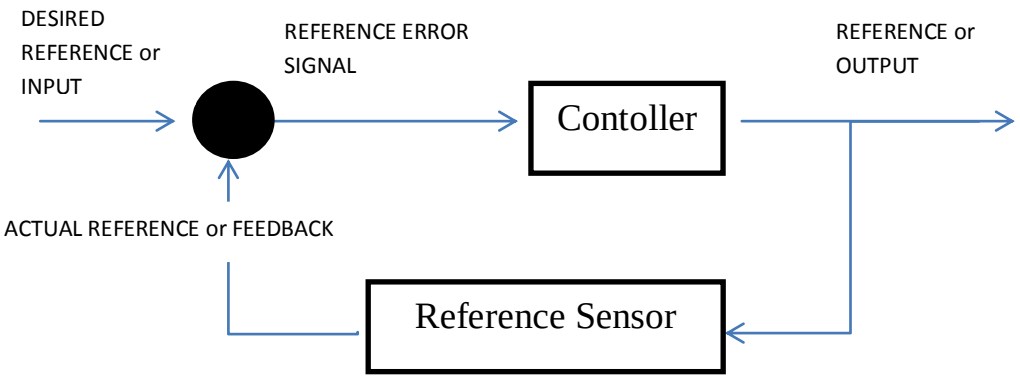

Figure 2.2: Feedback Control System diagram

Sources:M.Farid, 2008

2.2 RC Servo Motor

A servo motor is one kind of electric motor whose speed or position is controlled by a closed loop feedback circuit (Zarko,2006). Servo motors have rapid acceleration and deceleration capability made possible by high torque-to-inertia ratio(Basu, 2005). Pahuja (2012) has stated that DC servo motors have a high ratio of starting torque to inertia and therefore they have a faster dynamic response. With the characteristics of high dynamic response and precision make them suitable for motion control applications, such robot arms and other machine tools.The rotor construction of servo motor made of special materials with less weight to decrease the inertia of armature but capable to produce the necessary magnetic flux. Low rotor inertia increase the capability of immediately starting and stopping during the on-off conditions. The high cost of servo motor becomes major issue. Therefore the small scale manufactures or users cannot afford to use this type of DC Motor. DC Servo Motor have a large market share in the Industry Automation & Drive Technologies. The common problems in controlling the servo motor of speed and position is the tuning of the parameters. Many different techniques have been proposed in order to overcome this problem. Fuzzy logic is one of the method which implemented to handle this situation (Haidar, 2013). The figure 2.3 shows a field controlled DC servo motor.

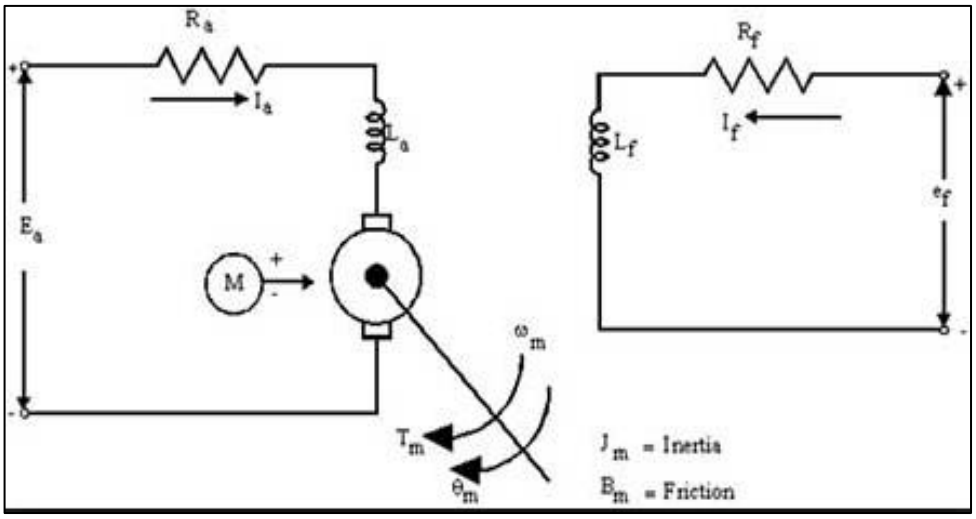

Figure 2.3: Field Controlled DC Servo Motor

Sources: P.Pahuja, 2012

The symbol are*f e* -applied field voltage(input), *f i*-field current, *f R* -field resistance, *f L* -field inductance, *a I* -armature current which is held constant, Θ - position of shaft (taken as output).The wound field DC motors can be controlled by either controlling the armature voltage or controlling the field current. To design feedback control for systems with time delay, it is necessary to consider the fact that the system's future behaviours depend not only on the current value of the state variables, but also some past history of the state variables.

2.3 Ball Valve

Ball valve is one type of valve that usually used in industrial application as they very versatile, supporting pressures up to 1000 bar and temperatures up to 250ºC. The ball valve has five part all of them.

Figure 2.4 shows the ball valve part. Those parts are:

1. Body
2. Head
3. Ball
4. Lever handle
5. Stem

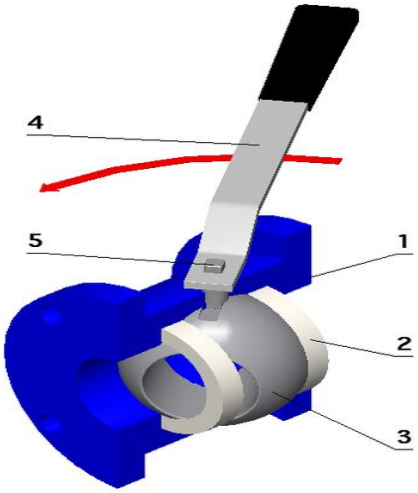

Figure 2.4: Ball Valve Part

Sources**:** R.Castelnuovo, 2006

This valve has a ball(sphere) with a hole or port, through the middle so when the port is in line with both ends of the valve, flow will occur inside it. When the valve is closed, the hole is perpendicular to the ends of the valve and the flow will be blocked (Castelnuovo,2006).Ball valves are made using an assortment of materials, some of which include brass, bronze, cast iron, copper ductile iron, metal alloys, stainless and other type of steels and plastics (including CPVC and PVC). There are many advantages using ball valve in this project:

Table 2.1: Ball valve advantages and limitations

Advantages	Limitations
Low cost	Poor throttling characteristics
High capacity	Prone to cavitation
Low leakage and maintaenance	
Tight sealing with low torque	

Sources: R.Castelnuovo,2006

2.4 Water Flow Sensor

Sensor is the device that measures a physical quantity and change it into a signal which can be read by an observer or by instrument (Izhan,2008).It's usually used in feedback control system which requires the output data to be channel back to the input for errors correction purpose.The sensor is what we called a device that worked as a transducer that changes a signal from the reality world such temperature, pressure and sound to electrical signal in digital form to make the computer can read it.

The sensors advantage to change the type of energy made it very applicable in any feedback control system process. It's also divided onto what type of energy transfer that they can detect (Frank,2000). In this project, water flow sensor is used as its can measure the fluid flow rate.Actually the real sensor is stated inside the water flow sensor calledHall Effect sensor. This sensor will vary its output voltage due to the response of magnetic field in corresponding pulse signal. The one that will activate the hall sensor is the small rotating wheel called water rotor that will roll when water flow through it. There still many types of flow sensor or flow metres that been used in open water channel case with their own methods.

Figure 2.5: Water Flow Sensor

Sources: C.Gantt, 2010

There are three methods for automatically measuring open channel flow which arehydraulic structures, area velocity and slope-hydraulic radius. (Dawson, 1998)Hydraulic structures it most common method of measuring open channel flow. A calibrated restriction inserted into the channel controls the shape and velocity of the flow. The flow rate is then determined by measuring the liquid level in or near the restriction. The restricting structures are called *primary measuring device.* They divided into two categories- weirs and flumes.

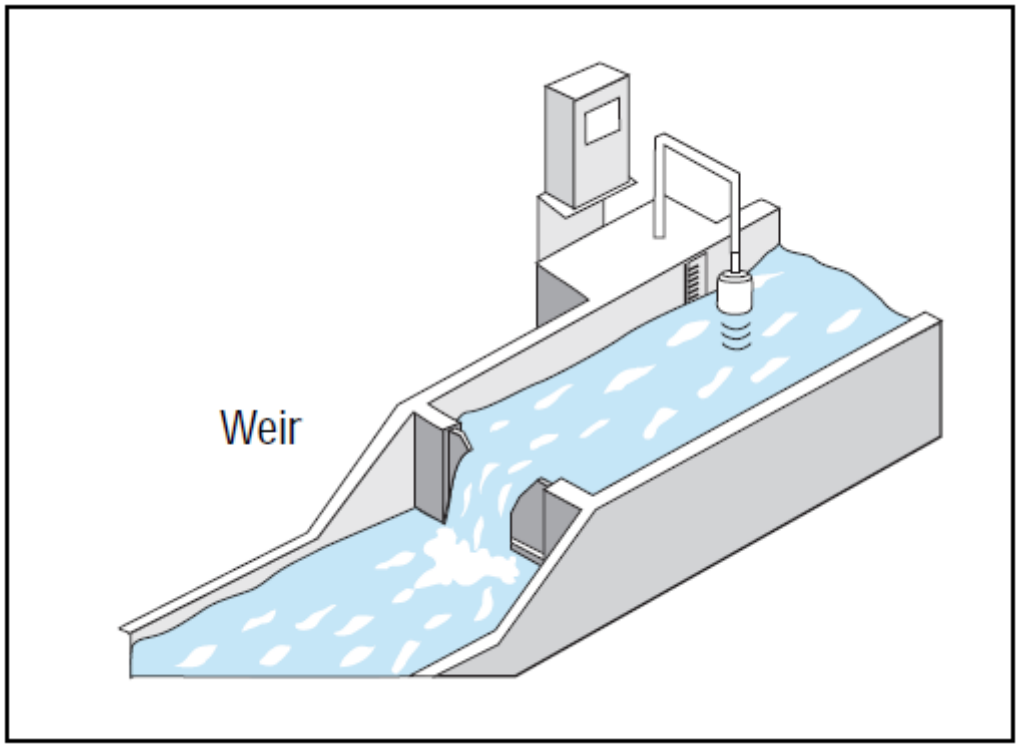

Figure 2.6: Non-contacting ultrasonic sensors are often used to measure the level upstream from a weir.

Sources: B.Dawson.1998

The flow rate over a weir is determined by measuring the liquid depth in the pool upstream from the weir.

A flume is specially shaped open channel flow section providing a restriction in channel area and/or a change in channel slope. The flow rate in the channel is determined by measuring the liquid depth at a specific point in the flume. The most common flume is the Parshall Flume (Dawson, 1998).The flow rate is determined by measuring the liquid one third of the way into converging section.

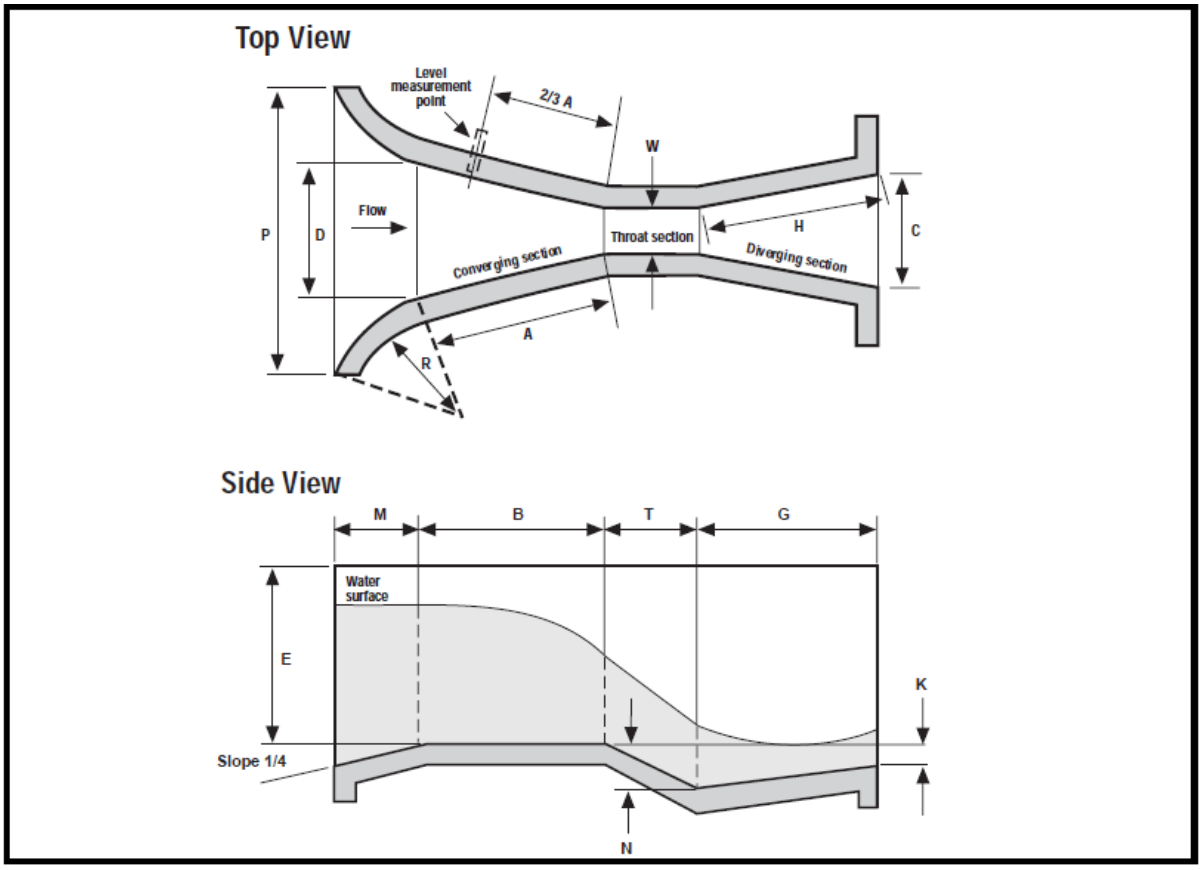

Figure 2.7: Parshall Flume top view and side view

Sources: B.Dawson, 1998

A secondary measuring devices, or open channel flow meter, is used in conjunction with a primary device to measure the rate of flow in an open channel. The flow meter measures the liquid level at one point in the channel, and then converts this measurement into flow rate based on the known level-to-flow rate relationship of the weir or flume.

There are several sensors used for measuring the level in the channel. The most common are ultrasonic sensors, bubblers and submerged pressure transducers (Dawson, 1998). Most modern open channel flow meters use software to convert the measured level into flow rate such the flow water sensor.

The second method, area velocity method is calculated flow rate by multiplying the area of the flow by its average velocity. This is often referred to as the continuity equation (Dawson, 1998).

$$Q = AxV \qquad (2.1)$$

Most area velocity flow meters use a single sensor to measure flow rate such as in figure 2.8. Doppler ultrasonic sensor is used to measure average flow velocity, pressure transducer measures the level in the channel. The flow meter converts this level into the area of the flow based on the size and shape of the channel. The main advantage using area velocity method are it can be used to measure flow under a wide range of conditions and does not require the installation of a weir or flume.

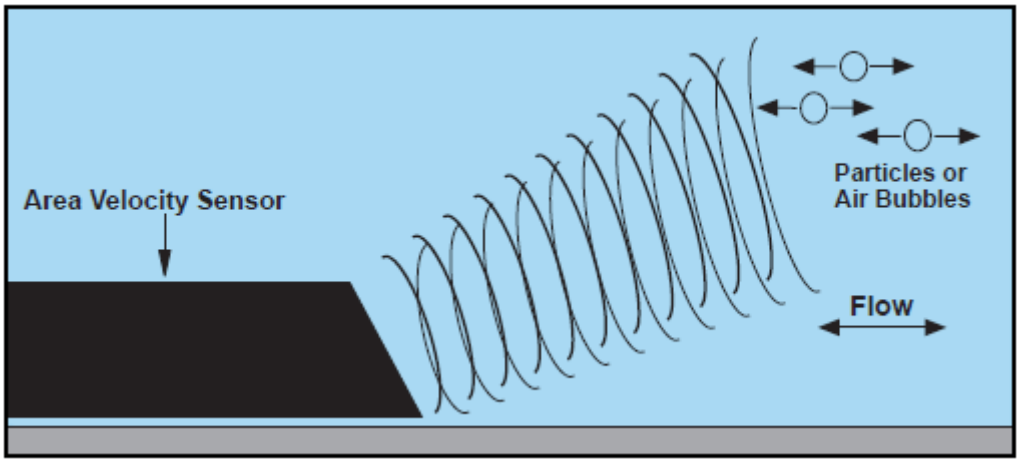

Figure 2.8: Area velocity flow meters

Sources: B.Dawson, 1998

The third method is using slope-hydraulic radius. Various equations are used to estimate flow rate and the most popular is *Manning formula*(Dawson,1998).

$$Q = \frac{KAR^{2/3}S^{1/2}}{n} \qquad (2.2)$$

Where Q is flow rate, A is cross sectional area of flow, R is hydraulic radius (cross sectional area divided by wetted perimeter), S is slope of the hydraulic gradient, n is

the roughness coefficient based on channel material and condition and K is the constant dependent upon units.

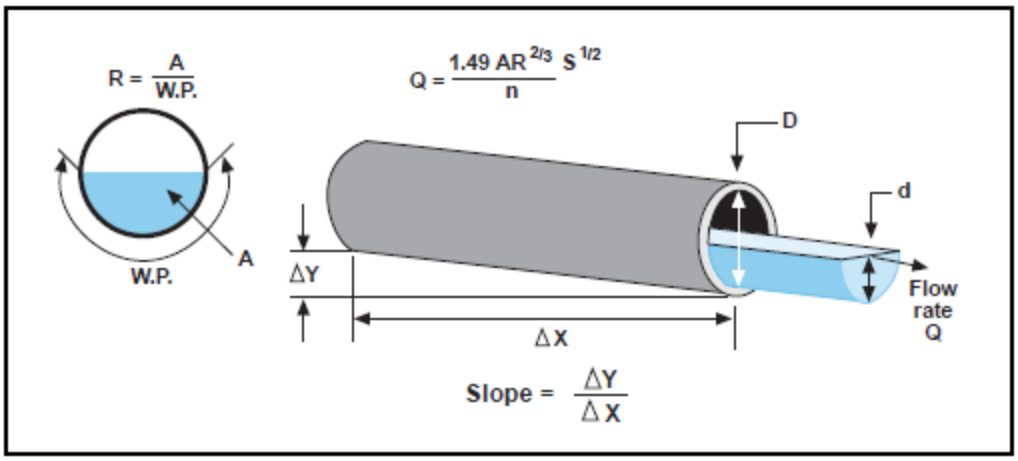

Figure 2.9: Manning formula application

Sources**:** B.Dawson,1998

The Manning formula is not a accurate as the hydraulic structures and area velocity methods but it can provide sufficient accuracy in some applications. It also does not require weir or flume**.**

2.5 Arduino Microcontroller

Arduino microcontroller is a small computer board which is easy to use besides is something come with open-source, which means hardware is reasonably priced and development software is free. With Arduino, ones can write programs and freely creating an interface circuits to read switches and other sensor, and also controlling motors and lights with a very simple steps (Durfee, 2011).Figure 2.10 shows the Arduino board looks like.